DOCUMENT RESUME

ED 224 818 TM 820 896

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TITLE Cognitive Capacity Usage During Prose Processing.
PUB DATE 22 Mar 82
NOTE 10p.; Paper presented at the Annual Meeting of the American Educational Research Association (66th, New York, NY, March 19-23, 1982).
PUB TYPE Speeches/Conference Papers (150) -- Reports - Research/Technical (143)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Cognitive Measurement; *Cognitive Processes; Higher Education; *Prose; *Questioning Techniques; *Reaction Time; Reading Processes; Responses
IDENTIFIERS *Mathemagenics; *Secondary Task Method

ABSTRACT

The secondary task method is utilized to assess cognitive capacity usage during, and immediately following, interspersed mathemagenic questions of different levels. The method also assesses the relationship between this usage and prose material recalled or recognized from differing positions and different types. The experiment involved 120 undergraduate students in four groups: interspersed questions with secondary task (questions and probe), secondary task only (probe only), question only, and no questions and no probe. Interspersed questions were found to improve subsequent test performance and meaningful questions were found to have more impact on later performance than rote questions. The findings were consistent with mathemagenic research. (Author/PN)

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Cognitive Capacity Usage During Prose Processing

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Paper presented to the American Educational Research Association, March 22, 1982
New York, New York

TM 820 896

In 1965 Rothkopf coined the term Mathemagenic Behavior (behaviors that "give birth to new learning") to encompass such things as what the learner pays attention to, for how long, and at what level he processes prose materials. To date research has focused on the placement of adjunct questions to elicit forward or backward processing (Rickards, 1979). Learner attention to material and cognitive level of processing have largely been inferred from test performance immediately following learning trials (Duell, 1974; Felker & Dapra, 1975; and Mayer, 1975). No attempts have been made to measure either attention or level of processing in a more direct fashion. Such measurements are possible however, using the established methodology of cognitive capacity usage.

Since Broadbent (1958) postulated a limited-capacity cognitive processor, the idea of such a "working memory" has been an important one in cognitive psychology. The technique (usually referred to as the secondary task method) for measuring the amount of cognitive capacity engaged in a given task is relatively simple: As the primary task (such as prose learning or motor task formulation) is taking place, a secondary signal occurs and the reaction time (RT) to the signal is measured (Posner & Boies, 1971). The rationale for such a method (see Britton, Piha, Davis & Wehauson, 1978; Kahneman, 1973; and Kerr, 1973) is that the more cognitive capacity being used for the primary task, the less is available for the secondary task and the slower the reaction will be to the secondary stimulus. (The classic demonstration is to ask a colleague to multiply 37 by 8 as you are walking down a hallway. Usually he will slow down or stop walking.) Recently Britton (Britton, Westbrook & Holdredge, 1978; and Britton, Meyer, Simpson, Holdridge & Curry, 1979) used such a secondary-task method to measure cognitive capacity engaged during

the reading of text materials of differing difficulties and organizational characteristics.

The current investigation utilized the secondary task method to assess cognitive capacity usage during, and immediately following, interspersed mathemagenic questions of different levels (superordinate and subordinate) and to assess the relationship between this usage and prose material recalled or recognized from differing positions (on question and after question) and of different types (main ideas versus details). It was predicted that rote questions would take up less cognitive capacity than meaningful questions (reflected by more rapid RT's to a concurrent secondary task) and that rote questions would have a less pervasive attention effect (reflected by relatively more rapid RT's to a subsequent secondary task). These predictions were based on the idea that semantic (meaningful) processing is at a "deeper" level (see, for example, Craik & Lockhart, 1972; and Lockhart, Craik & Jacoby, 1975) than rote learning and hence engages more cognitive capacity. Moreover, it was predicted that periods of high cognitive capacity usage (reflected by slower RT's) would be associated with increased recall or recognition for both main ideas and details of the text passage.

Method

Participants. Participants for the experiment were 120 undergraduate students randomly assigned to four groups of thirty each. The two groups exposed to the secondary task were tested individually, the remaining two groups were tested as groups.

Materials. Prose passages describing the mythical country of Mala which were developed by Bruning (1968) and have been used extensively in

mathemagenic research (e.g., Rickards, 1976; Rickards, Anderson, and McCormic, 1976; Rickards & Denner, 1978; Rickards & DiVesta, 1974). The passages are comprised of paragraphs containing one general (superordinate) idea and three specific detail (subordinate) sentences. Text questions were developed which were targeted on either details (rote learning) or general concepts (meaningful learning). Three questions of either type were placed at the end of each three paragraphs alternating randomly at either the top or the bottom of a page. A Lafayette 63014 Multi-choice Reaction Time apparatus was used to measure reaction times. Bruning's (1968) post-test comprised of 48 items (24 subordinate and 24 superordinate) was used to assess recall of prose passages.

Design and procedures. The experiment utilized four groups; interspersed questions with secondary task (questions & probe), secondary task only (probe only), question only, and no questions & no probe.

For the questions & probe and probe only groups a warm-up phase was used to familiarize the participants with the task and allow them to practice responding to the click probe with the reaction time device. Each participant was then presented with a booklet. The experimenter sat behind the students to record reaction times and monitor his/her progress through the material in order to place the click probe. Two probes were placed on those questions at the top of the page and after the questions appearing at the bottom of the page. (In the probe only group probes were placed on passage material in the same location.) Top and bottom were used equally on an alternate basis with a page of text following each question cluster. Rote and meaning questions also appeared equally and were counterbalanced across placement. In all, thirteen passage pages (four top, four bottom crossed with four rote, four meaning question clusters with five fillers) were used. (See Figure 1) The questions only and no questions and no probe groups read through the

Page No.	Question Location	Question Type	Probe
1	Bottom	Rote	
2	None		XX (after)
3	Top	Meaning	XX (on)
4	Bottom	Meaning	
5	None		XX (after)
6	Top	Rote	XX (on)
7	Bottom	Meaning	
8	None		XX (after)
9	Top	Meaning	XX (on)
10	Bottom	Rote	
11	None		XX (after)
12	Top	Rote	XX (after)
13	None		

Figure 1 Presentation Plan

materials appropriate to their assignments and answered the post-test questions.

Analysis. A 2-way analysis of variance for the within subject factors of question type (rote or meaningful) and placement (on question or after) of probe was used to determine the effects of these factors upon cognitive capacity as measured by reaction time for the questions and probe group. Two one-way analyses of variance for each question type (subordinate or superordinate) by the between subject factor of group (questions & probe, probe only, questions only and no questions & no probe) were used to determine the effects of these factors upon prose recall as measured by post test performance.

Results

As may be seen in Table 1, the mean participant reaction time to the secondary task was over two tenths of a second longer for meaningful questions ($\overline{X}$ = .709) than for rote questions ($\overline{X}$ =.476). This difference was statistically significant, $F(1,87) = 283.21$, $p < .0001$, $MSe = .005$. Mean reaction times for rote and meaningful questions did not differ as a result of placement on, or after questions. These results are qualified however, by an interaction between question type and probe placement, $F(1,87) = 29.93$, $p < .0001$, $MSe = .005$. This interaction, depicted in Figure 2, is the result of relatively higher and lower mean reaction times to the secondary probe task when placed on meaningful and rote questions respectively when compared to placement after such questions. Thus, while meaningful questions result in more cognitive capacity engagement both on and after meaningful questions relative to rote questions (both are statistically different as determined by Duncan's multiple range test, $p < .05$), it may be seen that reading rote

TABLE 1

Mean Reaction Times to the Secondary Task When Placed On or After, Rote and Meaningful Text Questions

Probe Placement	Question Type: Rote	Meaningful	Mean
On Question	.439	.747	.593
After Question	.514	.671	.593
$\bar{X}$	.476	.709	

NOTE: N = 30

TABLE 2

Mean Number of Correct Responses to Superordinate And Subordinate Post-Test Questions for No-Questions, Interspersed Text Questions, and Interspersed Text Questions With Secondary Task

Group	Question Type [a]: Subordinate	Superordinate	Mean
No Questions & No Probe	5.83	7.4	6.62
Questions Only	10.06	12.03	11.05
Questions & Secondary Task	8.73	15.50	12.12
Probe Only	11.70	14.33	13.01
$\bar{X}$	9.08	12.31	

NOTE: N = 120; 30 per group

[a] 48 total questions; 24 each type

questions engages less cognitive capacity than reading and that interspersing meaningful text questions results in a "residual," higher level of capacity engagement. The effect of this differential engagement may be more clearly understood when considered in conjunction with the content test results displayed in Table 2. As expected, superordinate questions ($\bar{X}$ = 12.31) were generally answered correctly more often than subordinate questions ($\bar{X}$ = 9.08). Also as expected, the group which received no interspersed text questions, performed less well ($\bar{X}$ = 6.62) than either the questions only group ($\bar{X}$ = 11.05) or the questions & probe group ($\bar{X}$ = 12.11). Surprising however, was the performance of the probe only group ($\bar{X}$ = 13.01). Again the findings of main effect were qualified by an interaction between question type and group, $F(3,116) = 13.96$, $p < .0001$, $MSe = 9.01$. As may be seen, in Figure 3, this interaction is largely th result improved test performance on superordinate items for the experimental questions & probe group relative to the other groups.

A one-way analyses on group performance for superordinate questions detected differences ($F(3,116) = 8.84$, $p < .0011$, $MSe = 43.46$), which *a posteriori* comparisons showed to be the result of differences between the performance of the questions & probe group ($\bar{X}$ = 15.50), the probe only group ($\bar{X}$ = 14.33) and the question only group ($\bar{X}$ = 12.03) relative to the no questions & no probe group ($\bar{X}$ = 7.4). No other *a posteriori* comparisons were significant. The overall test for subordinate questions was also significant ($F(3,116) = 5.737$, $p < .001$, $MSe = 32.24$) due to the difference between both the questions only group ($\bar{X}$ = 10.06) and the probe only group ($\bar{X}$ = 11.70), relative to the no questions and no probe group ($\bar{X}$ = 5.83). No other comparisons were significant. Thus, all three experimental manipulations produced differences relative to the control group of no probe & no questions for superordinate test

items but did not differ amongst themselves while for subordinate items only the single manipulations of probe only and questions only resulted in differential performance relative to the control group.

Discussion. The results of this study are significant in two areas, one practical and one theoretical. First, the findings that interspersed questions improve subsequent test performance and that meaningful questions have more impact on later performance than rote questions, is consistent with a large body of mathemagenic research. The practical implications of such findings are clear and important. The manipulation of text questions to cause the learning to pay attention to relevant materials longer, and at a "deeper" level is potentially a major contribution to materials design technology. Coupled with the second finding of theoretical importance, that meaningful questions engage more cognitive capacity than rote questions both as they are asked and after they are asked, it becomes more significant. It means that a technique such as the distracter task used in this experiment (which is well within the capability of most formative evaluation "shops" involved with major materials development) can be used to test how "engaging" a question is during learner tryout. It can mean more effective questions and question placement, selected on a very cost-effective basis.

Perhaps more important however, is the power of the secondary task itself. While this effect has been mentioned by others the finding of such a robust "artifact" was surprising. It implies that much of the previous cognitive capacity research may need to be replicated and that future research using the secondary task paradigm should consider "warm-ups" of sufficient duration to allow this "novelty or attentional effect to dissipate.